# CERTIFICATION

I, Yoshihiro KATSU, 26-10, Tenjin 2-chome, Nagaokakyo-shi, Kyoto-fu, Japan, do hereby certify that I am conversant with the English and Japanese language, and I further certify that to the best of my knowledge and belief that the attached English translation is a true and correct translation of the Japanese patent applications No. 2000-363316 filed on November 29, 2000.

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[Title of the Invention] SURFACE ACOUSTIC WAVE FILTER

[Claims]

[Claim 1] A surface acoustic wave filter, comprising:

a piezoelectric substrate;

a plurality of IDTs which is formed on said piezoelectric substrate, and which is arranged along the propagation direction of a surface acoustic wave;

a balanced-to-unbalanced conversion function; and

among said plurality of IDTs, the IDTs on the opposite sides being disposed in an approximate point-symmetry about the IDT positioned at the center in the propagation direction of a surface acoustic wave.

[Claim 2] A surface acoustic wave filter, comprising:

a piezoelectric substrate;

first to third IDTs which are formed on said piezoelectric substrate, and which are sequentially arranged along the propagation direction of a surface acoustic wave;

an unbalanced signal terminal connected to the first and third IDTs; and first and second balanced signal terminals each electrically connected to the opposite ends of the second IDT;

each of the first to third IDTs having first and second end portions positioned on the opposite sides thereof in the direction perpendicular to the propagation direction of a

surface acoustic wave;

the first end portion of the first IDT and the second end portion of the third IDT being each electrically connected to said unbalanced signal terminal; and

the second end portion of the first IDT and the first end portion of the third IDT being each connected to the ground potential.

[Claim 3] A surface acoustic wave filter, comprising:

a piezoelectric substrate;

first to third IDTs which are formed on said piezoelectric substrate, and which are sequentially arranged along the propagation direction of a surface acoustic wave; an unbalanced signal terminal connected to the second IDT; and first and second balanced signal terminals each electrically connected to the first and third IDTs;

each of the first to third IDTs having first and second end portions positioned on the opposite sides thereof in the direction perpendicular to the propagation direction of a surface acoustic wave;

the first end portion of the first IDT and the second end portion of the third IDT being each electrically connected to the first balanced signal terminal; and

the second end portion of the first IDT and the first end portion of the third IDT being each electrically connected to the second balanced signal terminal.

[Claim 4] A surface acoustic wave filter in accordance with any one of claims 1 to 3, wherein the IDT electrically connected to said balanced signal terminals has an even number of electrode fingers.

[Claim 5] A surface acoustic wave filter in accordance with any one of claims 1 to 4, wherein at least one IDT is constituted of a plurality of IDT portions divided along the direction perpendicular to the propagation direction of a surface acoustic wave.

[Claim 6] A surface acoustic wave filter in accordance with any one of claims 1 to 5, further comprising at least one surface acoustic wave resonator connected to said surface acoustic wave filter in series and/or parallel.

[Claim 7] A communication device having the surface acoustic wave filter in accordance with any one of claims 1 to 6.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a surface acoustic wave filter used as, for example, a band pass filter in a portable telephone, or the like, and more particularly, to a surface acoustic wave filter having a balanced-to-unbalanced conversion function, namely, a balun function.

[0002]

[Description of the Related Art]

With the reduction in size and weight of portable telephones in recent years, the reduction in the number of components of a portable telephone and their miniaturization are progressing. In addition, components combining a plurality of functions are being developed.

[0003]

In such a situation, as surface acoustic filters used for the RF(radio frequency) stage of portable telephones, ones which have a balanced-to-unbalanced conversion function, namely, a balun function have been studied, and are mainly used in GSM portable telephones.

[0004]

Fig. 11 is a schematic plan view showing the electrode structure of a conventional surface acoustic wave filter having a balanced-to-unbalanced conversion function.

In the surface acoustic wave filter 100, first to third IDTs (interdigital transducers) 101 to 103 are arranged on a piezoelectric substrate (not shown) along the direction of a surface acoustic wave. Reflectors 104 and 105 are disposed on the opposite sides of the area where the IDTs 101 to 103 are provided, in the direction of a surface acoustic wave.

[0005]

One end of each of the IDTs 101 and 103 is electrically connected to an unbalanced signal terminal 108, and the

other end of each of them is connected to the ground potential. One end of the IDT 102 is electrically connected to a first balanced signal terminal 106, and the other end thereof is electrically connected to a second balanced signal terminal 107.

[0006]

[Problems to be Solved by the Invention]

The magnitude of the attenuation outside the pass band of a surface acoustic wave filter having a balanced-to-unbalanced conversion function, significantly depends on the degree of balance of the surface acoustic wave filter. The degree of balance is represented as the difference between the transmission characteristic between the unbalanced signal terminal and the first balanced signal terminal, and the transmission characteristic between the unbalanced signal terminal and the second balanced signal terminal. Of these differences in the transmission characteristic, the difference in the amplitude characteristic is called "amplitude balance degree" and the difference in the phase characteristic is called "phase balance degree".

[0007]

Here, when a surface acoustic filter having a balanced-to-unbalanced conversion function is assumed to be a device having first to third ports, and, for example, the unbalanced input terminal thereof is the first port, and the

first and second balanced output terminals thereof are assumed to be the second and third ports, respectively, the amplitude balance degree and the phase balance degree are represented by the following equations:

[0008]

[Mathematical Expression 1]

Amplitude balance degree = $|A|$, $A = |20\cdot\log(S21)| - |20\cdot\log(S31)|$, and

Phase balance degree = $|B - 180|$, $B = |\angle S21 - \angle S31|$

[0009]

Here, S21 denotes the transmission coefficient from the first port to the second port, and S31 denotes the transmission coefficient from the first port to the third port.

Ideal values of the amplitude balance degree and the phase balance degree in the outside of the pass band of the filter are assumed to be 0 dB for the amplitude balance degree, and 0° for the phase balance degree. The magnitude of the attenuation outside the pass band in the filter having such ideal degrees of balance is infinity. Therefore, by bringing the amplitude balance degree and the phase balance degree close to 0 dB and 0 degree, respectively, the attenuation outside the pass band can be made large.

[0010]

In the surface acoustic wave filter 100 shown in Fig.

11, the degree of balance has been inferior and thereby the attenuation outside the pass band has been insufficient, although a balanced-to-unbalanced conversion function can be realized.

The object of the present invention is to eliminate the above-described drawback, and to provide a longitudinally-coupled resonator-type surface acoustic wave filter which is capable of improving the degree of balance outside the pass band in addition to having a balanced-to-unbalanced conversion function, and which can thereby increase the attenuation outside the pass band.

[0011]

[Means for Solving the Problems]

In accordance with a first invention of the present application, there is provided a surface acoustic wave filter that comprises a piezoelectric substrate; a plurality of IDTs which is formed on the piezoelectric substrate, and which is arranged along the propagation direction of a surface acoustic wave; and a balanced-to-unbalanced conversion function. Among the plurality of IDTs, the IDTs on the opposite sides are disposed in an approximate point-symmetry about the IDT positioned at the center in the propagation direction of a surface acoustic wave.

[0012]

In accordance with a second invention of the present

application, there is provided a surface acoustic wave filter that comprises a piezoelectric substrate; first to third IDTs which are formed on the piezoelectric substrate, and which are sequentially arranged along the propagation direction of a surface acoustic wave; an unbalanced signal terminal connected to the first and third IDTs; and first and second balanced signal terminals each electrically connected to the opposite ends of the second IDT. In this surface acoustic wave filter, each of the first to third IDTs has first and second end portions positioned on the opposite sides thereof in the direction perpendicular to the propagation direction of a surface acoustic wave; the first end portion of the first IDT and the second end portion of the third IDT are each electrically connected to the unbalanced signal terminal; and the second end portion of the first IDT and the first end portion of the third IDT are each connected to the ground potential.

[0013]

In accordance with a third invention of the present application, there is provided a surface acoustic wave filter that comprises a piezoelectric substrate; first to third IDTs which are formed on the piezoelectric substrate, and which are sequentially arranged along the propagation direction of a surface acoustic wave; an unbalanced signal terminal connected to the second IDT; and first and second

balanced signal terminals each electrically connected to the first and third IDTs. In this surface acoustic wave filter, each of the first to third IDTs has first and second end portions positioned on the opposite sides thereof in the direction perpendicular to the propagation direction of a surface acoustic wave; the first end portion of the first IDT and the second end portion of the third IDT are each electrically connected to the first balanced signal terminal; and the second end portion of the first IDT and the first end portion of the third IDT are each electrically connected to the second balanced signal terminal.

[0014]

In the above-described conventional surface acoustic wave filter 100, since the degree of balance outside the pass band has been inferior, the attenuation outside the pass band has not been sufficient. The reason for this is assumed as follows. Since the balanced signal terminal 106 is surrounded by the signal line connected to the unbalanced signal terminal 108, a parasite capacitance inserted between input and output terminals in parallel has a large influence, and conversely, since the balanced signal terminal 107 is adjacent to the wiring connected to the ground terminal, a parasitic capacitance added between the signal line and the ground line in parallel has a large influence. That is, the manners wherein parasitic capacitances are added to the

balanced signal terminals 106 and 107 are different from each other, and thereby the degree of balance outside the pass band would deteriorate.

[0015]

Under the above-described assumption, the present inventor considered that, if an electrode is formed so that parasitic impedances are each added to a pair of balanced signal terminals substantially equally, the degree of balance outside the pass band will be improved, and that the attenuation outside the pass band will thereby be increased. On the basis of this consideration, the present invention has been made.

[0016]

Accordingly, the surface acoustic wave filter in accordance with the present invention is characterized in that it has an electrode structure such that parasitic impedances are each added to the first and second balanced signal terminals substantially equally.

[0017]

More specifically, in the first invention, among the plurality of IDTs, the opposite IDTs are disposed in an approximate point-symmetry about the IDT positioned at the center in the propagation direction of a surface acoustic wave, and thereby, as can be seen from the embodiment shown later, the parasitic impedances added to the first and

second balanced signal terminals are made substantially equal to each other.

[0018]

In the second invention, the first end portion of the first IDT and the second end portion of the third IDT are each connected to the unbalanced signal terminals, and the second end portion of the first IDT and the first end portion of the third IDT are connected to the ground potential, whereby, as can be seen from the embodiment shown later, parasitic impedances are each added to the first and second balanced signal terminals substantially equally.

[0019]

In the third invention, the first end portion of the first IDT and the second end portion of the third IDT are each electrically connected to a first balanced signal terminal, and the second end portion of the first IDT and the first end portion of the third IDT are each electrically connected to a second balanced signal terminal, whereby parasitic impedances are each added to the first and second balanced signal terminals substantially equally.

[0020]

In a particular aspect of the present invention in accordance with claims 1 to 3, the number of electrode fingers of the IDT electrically connected to the balanced signal terminal is made an even number, the numbers of the

electrode fingers electrically connected to the first and second balanced signal terminals connected to the IDT are thereby made equal, so that the degree of balance within the pass band is improved, resulting in an increased attenuation outside the pass band.

[0021]

In another aspect of the surface acoustic wave filter in accordance with the present invention, at least one IDT connected to a balanced signal terminal or an unbalanced signal terminal has a plurality of IDT portions divided in the direction perpendicular to the propagation direction of a surface acoustic wave. In the IDT thus having a plurality of IDT portions divided in the direction perpendicular to the propagation direction of a surface acoustic wave, since the impedance thereof is increased, a surface acoustic wave filter wherein the input and output impedances thereof are different from each other, can be provided.

[0022]

In still another aspect of the surface acoustic wave filter in accordance with the present invention, at least one surface acoustic wave resonator connected to the above-described surface acoustic wave filter in series and/or parallel, is further included. Thus connecting at least one surface acoustic wave resonator to the surface acoustic wave filter in accordance with the present invention in series

and/or parallel, enables the attenuation in the vicinity of the pass bands to be enhanced.

[0023]

The surface acoustic wave filter in accordance with the present invention is suitably used for, e.g., the band-pass filter employed for the RF stage of a portable telephone. Therefore, by using the surface acoustic wave filter in accordance with the present invention, a communication device provided with a band-pass filter which has a balanced-to-unbalanced conversion function as well as exhibits a large attenuation outside the pass band, and which is compact and superior in the frequency characteristic can be provided.

[0024]

[Description of the Embodiments]

The present invention will be clarified by the following specific description of the embodiments of the present invention with reference to the accompanying drawings.

[0025]

First Embodiment

Fig. 1 is a schematic plan view showing a surface acoustic wave filter in accordance with a first embodiment of the present invention.

[0026]

The surface acoustic wave filter 200 in accordance with this embodiment is arranged to be applied to a receiving filter used for the RF stage of a PCS portable telephone.

The surface acoustic wave filter 200 is constructed by forming an electrode structure shown in Fig. 1 on a piezoelectric substrate A of which the outline is schematically shown in the figure. In this embodiment, the piezoelectric substrate A is formed using a 40 ± 5°, Y-cut, X-propagation $LiTaO_3$ substrate.

[0027]

A longitudinally-coupled resonator-type surface acoustic wave filter 201 and surface acoustic wave resonators 202 and 203 are formed on the piezoelectric substrate A.

The longitudinally-coupled resonator-type surface acoustic wave filter 201 has first to third IDTs 204 to 206. Reflectors 207 and 208 are disposed on the opposite sides of the area where the IDTs 204 to 206 are provided, in the direction of a surface acoustic wave.

[0028]

The electrode structure and the surface acoustic wave resonators 202 and 203 which constitute the longitudinally-coupled resonator-type surface acoustic wave filter 201, are formed of Al.

Each of the IDTs 204 to 206 has a pair of comb

electrodes. Here, in the IDTs 204 to 206, the end portions on the opposite sides in the direction perpendicular to the direction of a surface acoustic wave are represented as first and second end portions 204a and 204b; 205a and 205b; and 206a and 206b, respectively. The end portions 204a to 206b correspond to the end portions of one-side comb electrodes of the IDTs 204 to 206, respectively.

[0029]

The first end portion 204a of the IDT 204 is connected to an unbalanced signal terminal 209 via the surface acoustic wave resonator 202, and the second end portion 206b of the IDT 206 is connected to the unbalanced signal terminal 209 via the surface acoustic wave resonator 203. That is, the surface acoustic wave resonators 202 and 203 are each connected to longitudinally-coupled resonator-type surface acoustic wave filter 201 in series.

[0030]

The second end portion 204b of the IDT 204 and the first end portion 206a of the IDT 206 are each connected to the ground potential.

The first end portion 205a of the IDT 205 is connected to the first balanced signal terminal 210, and the second end portion 205b of the IDT 205 is connected to the second balanced signal terminal 211.

[0031]

The surface acoustic wave filter 200 in accordance with this embodiment is characterized in that among the plurality of IDTs 204 to 206, the opposite IDTs are disposed in an approximate point- symmetry about the IDT 205 positioned at the center, and that the first end portion 204a of the IDT 204, and the second end portion 206b of the IDT 206 are connected to the unbalanced signal terminal 209 as described above, whereby the degree of balance outside the pass band is enhanced, and the attenuation outside the pass band is increased, as can be seen from the following experimental results.

[0032]

The above-described surface acoustic wave filter 200 was constructed on the basis of the following design, and the frequency characteristic thereof was measured.

electrode finger crossing width W of IDTs 204 to 206 = 78.7λI (here, λI is the wavelength of surface acoustic wave determined by the IDTs);

number of electrode fingers of each of the IDTs 204 to 206 ... IDT 204: 25, IDT 205: 41, and IDT 206: 25;

wavelength in IDT, λI = 2.03 μm;

wavelength in the reflectors 207 and 208, λR = 2.05 μm;

number of electrode fingers of each of the reflectors = 100;

IDT-to-IDT distance = 0.77λI ("IDT-to-IDT distance"

refers to the intercentral distance of electrode fingers connected to mutually different potentials, in IDTs adjacent to each other);

IDT-to-reflector distance = 0.55λR ("IDT-to-reflector distance" refers to the electrode finger intercentral distance between an IDT and a reflector adjacent thereto);

duty ratio = 0.60;

film thickness of electrode = 0.08λI

As can be seen from Fig. 1, the electrode fingers 212 and 213 at the opposite sides of the IDT 205 in the propagation direction of a surface acoustic wave are made wider than the remaining electrode fingers, and thereby free surface portions in IDT-IDT distance areas are made smaller.

[0033]

The specifications of the surface acoustic wave resonators 202 and 203 are as follows:

crossing width W = 17.3λ;

number of electrode fingers of IDTs = 301

wavelength λ = 2.02 μm;

number of electrode fingers of each of the reflectors = 30 (however, in Fig. 1, the reflectors on the opposite sides of the IDTs are not shown)

IDT-to-reflector distance = 0.50λ;

duty ratio = 0.60;

film thickness of electrode = 0.08λ

For comparison, the conventional surface acoustic wave filter 300 shown in Fig. 3 was formed of the same material as that of the above-described embodiment, and the frequency characteristic thereof was measured. In the surface acoustic wave filter 300 shown in Fig. 3, a surface acoustic wave resonator 302 is connected to a longitudinally-coupled resonator-type surface acoustic wave filter 301 in series, and the longitudinally-coupled resonator-type surface acoustic wave filter 301 is connected to an unbalanced signal terminal 308 via the surface acoustic wave resonator 302. The longitudinally-coupled resonator-type surface acoustic wave filter 301 comprises first to third IDTs 303 to 305, and reflectors 306 and 307. In the surface acoustic wave filter 300, the first end portions 303a and 305a of the respective IDTs 303 and 305 are connected to the unbalanced signal terminal 308 via the surface acoustic wave resonator 302, and the second end portions of 303b and 305b of the respective IDTs 303 and 305 are connected to the ground potential. The first and second end portions 304a and 304b of the second IDT 304 are connected to first and second balanced signal terminal 309 and 310, respectively.

[0034]

That is, in the surface acoustic wave filter 300 shown in Fig. 3, the IDTs 303 and 305 are connected to the unbalanced signal terminal 308 through the first end

portions 303a and 305a, respectively. Herein, the configurations of the longitudinally-coupled resonator-type surface acoustic wave filter 301 and the surface acoustic wave resonator 302 are fundamentally the same as those of the longitudinally-coupled resonator-type surface acoustic wave filter 201 and the surface acoustic wave resonators 202 and 203, respectively. However, in the longitudinally-coupled resonator-type surface acoustic wave filter 301, the posture of the IDT 303 is inverted in order to adjust the phase. Also, the surface acoustic wave resonator 302 is formed so as to have a crossing width as twice large as that of the surface acoustic wave resonators 202 and 203.

[0035]

The frequency characteristic of the surface acoustic wave filter 200 in accordance with the above-described embodiment is illustrated in Fig. 2. On the other hand, the frequency characteristic of the conventional surface acoustic wave filter 300 prepared as described above, which is shown in Fig. 3, is illustrated in Fig. 4.

[0036]

As is evident from the comparison between Figs. 2 and 4, the surface acoustic wave filter 200 in accordance with the first embodiment allows the attenuation outside the pass band to be increased. For example, when comparing the attenuations of the first embodiment and the conventional

example at 0 to 1 GHz, the conventional example exhibits an attenuation of 30 dB, whereas the first embodiment exhibits an attenuation of 55 dB. That is, the first embodiment is improved in the attenuation by 25 dB over the conventional example. Then when comparing the attenuations of the first embodiment and the conventional example at 4 to 6 GHz, the conventional example exhibits an attenuation of 18 dB, whereas the first embodiment exhibits an attenuation of 32 dB, that is, the first embodiment is improved in the attenuation by 14 dB over the conventional example.

[0037]

The reason why the attenuation outside the pass band could be thus enhanced in this embodiment is assumed as follows.

As described above, in the conventional surface acoustic wave filter having a balanced-to-unbalanced conversion function, the one balanced signal terminal 309 is adjacent to the signal line, and the second balanced signal terminal 310 is adjacent to the ground line. Therefore, the influences of the parasitic impedance on the balanced signal terminals 309 and 310 significantly differ from each other, so that the degree of balance outside the pass band would deteriorate, and the attenuation outside the pass band would be insufficient.

[0038]

In contrast, in this embodiment, in which the IDTs 204 and 206 are connected to the unbalanced signal 209, mutually opposite ends of the IDTs 204 and 26, i.e., the first end portion 204a and the second end portion 206b are connected to the unbalanced signal terminal 209. Both balanced signal terminals 210 and 211, therefore, are adjacent to both the signal line and the ground line, and thereby the influences of parasitic impedance to the balanced signal terminals 210 and 211 become substantially equal to each other. In other words, since the IDTs 204 and 206 on the opposite sides are disposed in an approximate point-symmetry about the center IDT 205, the influences of parasitic impedance on the first and second balanced signal terminals 210 and 211 become substantially equal to each other, and consequently, the degree of balance outside the pass band would be improved, and the attenuation outside the pass band would be increased.

[0039]

Meanwhile, in this embodiment, the number of the electrode fingers of the IDT 205 connected to the balanced signal terminals 210 and 211 is set to be an odd number, but it is preferable that, like a longitudinally-coupled resonator-type surface acoustic wave filter 250 in accordance with a modification shown in Fig. 5, the number of the electrode fingers of the second IDT 205 positioned at the center in the propagation direction and connected to the

balanced signal terminals 210 and 211, be set to be an even number. In this case, since the numbers of the electrode fingers connected to the balanced signal terminals 210 and 211 become equal to each other, the degree of balance within the pass band can be more improved, and the attenuation outside the pass band can be more increased.

[0040]

The surface acoustic wave filter 250 is constructed in the same manner as the first embodiment, except that the number of the electrode fingers of the IDT 205 is different from that of the first embodiment, and that narrow-pitch electrode fingers are provided on the opposite sides of the gaps between the IDTs 204 and 205, and between the IDTs 205 and 206, unlike the first embodiment. Therefore, in such a configuration where narrow-pitch electrode fingers are provided, the effect of the present invention can be achieved, as in the case of the first embodiment.

[0041]

Second Embodiment

Fig. 6 is a schematic plan view showing the electrode structure of a surface acoustic wave filter in accordance with a second embodiment of the present invention. As in the case of the first embodiment, in the second embodiment, an electrode structure shown in the figure is formed on a piezoelectric substrate constituted of a 40 ± 5°, Y-cut, X-

propagation $LiTaO_3$ substrate.

[0042]

Herein, longitudinally-coupled resonator-type surface acoustic wave filter 401 is formed of an Al electrode.

The longitudinally-coupled resonator-type surface acoustic wave filter 401 comprises first to third IDTs 402 to 404 sequentially arranged along the propagation direction of a surface acoustic wave, and reflectors 405 and 406 disposed on the opposite sides of the area where the IDTs 402 to 404 are provided, in the direction of a surface acoustic wave.

[0043]

In this embodiment also, one-side end portions of the first to third IDTs 402 to 404 in the direction perpendicular to the propagation direction of a surface acoustic wave are represented as first end portions 402a, 403a, and 404a, and the other-side end portions are represented as the second end portions 402b, 403b, and 404b.

[0044]

The first end portion 403a of the second IDT 403 is electrically connected to an unbalanced signal terminal 409, and the second end portion 403b thereof is connected to the ground potential.

The first end portion 402a of the first IDT 402 and the second end portion 404b of the third IDT 404 are each

electrically connected to an first balanced signal terminal 407. On the other hand, the second end portion 402b of the IDT 402 and the first end portion 404a of the IDT 404 are each electrically connected to an second balanced signal terminal 408.

[0045]

The second embodiment is characterized in that, in the IDTs 402 and 404 each connected to the balanced signal terminals, the first end portion 402a of the first IDT 402 and the second end portion 404b of the third IDT 404 are each electrically connected to the first balanced signal terminal 407, while the second end portion 402b of the IDT 402 and the first end portion 404a of the IDT 404 are each electrically connected to the second balanced signal terminal 408. As in the case of the first embodiment, therefore, the second embodiment has a structure wherein the IDTs 402 and 404 are disposed in an approximate point-symmetry about the central IDT 403.

[0046]

In the IDT 402, therefore, the end portion 402a adjacent to the signal line connecting the unbalanced signal terminal 409 and the IDT 403, is connected to the balanced signal terminal 407, and the end portion 402b adjacent to the ground line is connected to the balanced signal terminal 408. Conversely, in the IDT 404, the end portion 404a

adjacent to the signal line is connected to the balanced signal terminal 408, and the end portion 404b adjacent to the ground line is connected to the balanced signal terminal 407. As is the case with the first embodiment, therefore, the influences of parasitic impedance on the first and second the balanced signal terminal 407 and 408 become substantially equal to each other. Thereby, in the second embodiment also, the degree of balance outside the pass band is improved, and the attenuation outside the pass band is enhanced as in the case of the first embodiment.

[0047]

In the second embodiment, the number of the electrode fingers of each of the IDTs 402 and 404 is set to be an odd number, but as shown in Fig. 7, by setting the number of the electrode fingers of the IDTs 402A and 404A connected to the balanced signal terminals 407 and 408 to be an even number, the numbers of the electrode fingers connected to the balanced signal terminals become equal to each other. Therefore, the degree of balance within the pass band can be more improved, leading to more increased attenuation outside the pass band.

[0048]

Meanwhile, in the longitudinally-coupled resonator-type surface acoustic wave filter shown in Fig. 6, the first to third IDTs 402 to 404 are used, that is, a three-IDT type

surface acoustic wave filter is used. However, as shown in Fig. 8, the present invention can also be applied to a five-IDT type longitudinally-coupled resonator-type surface acoustic wave filter which is formed by additionally disposing IDTs 411 and 412 on the opposite sides of the three IDTs. Furthermore, the present invention can also be applied to a longitudinally-coupled resonator-type surface acoustic wave filter having more IDTs.

[0049]

Third Embodiment

Fig. 9 is a schematic plan view explaining a surface acoustic wave filter in accordance with a third embodiment of the present invention. As in the case of the first embodiment, the surface acoustic wave filter 500 is constructed by forming an electrode structure shown in the figure on a piezoelectric substrate constituted of a 40 ± 5°, Y-cut, X-propagation $LiTaO_3$ substrate.

[0050]

Specifically, a longitudinally-coupled resonator-type surface acoustic wave filter 501, and surface acoustic wave resonators 502 and 503 connected thereto in series are formed of an Al electrode.

[0051]

The surface acoustic wave filter 500 in accordance with the third embodiment is constructed fundamentally in the

same manner as the surface acoustic wave filter 200 in accordance with the first embodiment. The surface acoustic wave filter 500 is different from the first embodiment in that, in the longitudinally-coupled resonator-type surface acoustic wave filter 501, the second IDT 505 at the center has a plurality of IDT portions 505A and 505B divided along the direction perpendicular to the propagation direction of a surface acoustic wave. In other respects, the surface acoustic wave filter 500 is the same as the first embodiment. Therefore, corresponding portions between the surface acoustic wave filter 500 and the first embodiment are given the same reference numerals, and the description about the first embodiment will be utilized here.

[0052]

In the same manner as the third embodiment, by dividing the second IDT 505 at the center into the first and second IDT portions 505A and 505B, the input impedance and the output impedance are made different by a factor of four. That is, since the IDT 505 is divided into two as described above, the impedances on the balanced signal terminals 510 and 511 sides are increased. Thereby a surface acoustic wave filter wherein the input and the output impedances thereof are made different from each other, wherein the degree of balance outside the pass band is improved, and wherein the attenuation outside the pass band is enhanced,

can be provided.

[0053]

In the third embodiment, the IDT 505 has been divided into two, and the impedances on the balanced signal terminal sides have been increased. Conversely, however, by dividing the IDTs 504 and 506 connected to the unbalanced signal terminal 509, the impedance on the unbalanced signal terminal side may be increased instead.

[0054]

Fig. 10 is a schematic block diagram explaining a communication device 160 constructed using the surface acoustic wave device in accordance with the present invention.

In Fig. 10, a duplexer 162 is connected to an antenna 161. A surface acoustic wave filter 164 and an amplifier 165 are connected between the duplexer 162 and an receiving-side mixer 163. An amplifier 167 and a surface acoustic wave filter 168 are connected between the duplexer 162 and a transmitting-side mixer 166. When the amplifier 165 and the mixer 166 are thus adaptable to balanced signals, the surface acoustic wave devices constructed in accordance with the present invention can be suitably used as the above-described surface acoustic wave filters 164 and 168.

[0055]

In the present invention, not only a 40 ± 5°, Y-cut, X-

propagation $LiTaO_3$ substrate, but various piezoelectric substrates can be used for the piezoelectric substrate. For example, a 64 to 72°, Y-cut, X-propagation $LiNbO_3$ substrate, a 41°, Y-cut, X-propagation $LiNbO_3$ substrate, or piezoelectric ceramic substrate can be used. Moreover, a substrate wherein a piezoelectric thin film is formed on an insulating substrate can also be employed.

[0056]

In the surface acoustic wave filter in accordance with the present invention, the surface acoustic wave resonator may be connected to the surface acoustic wave filter in any of the series and/or parallel connection modes, and the number of the surface acoustic wave resonator to be connected is not particularly limited.

[0057]

[Advantages]

As described above, in the surface acoustic wave filter in accordance with the first invention, since, among the plurality of IDTs, the IDTs on the opposite sides are disposed in an approximate point-symmetry about the IDT positioned at the center, parasitic impedances are each added to the first and second balanced signal terminals substantially equally, in the surface acoustic wave filter having a balanced-to-unbalanced conversion function, and thereby the degree of balance outside the pass band is

improved. This allows a surface acoustic wave filter exhibiting a large attenuation outside the pass band and having a balanced-to-unbalanced conversion function to be provided.

[0058]

In the surface acoustic wave filter in accordance with the second invention, each of the first to third IDTs has the first and second end portions positioned on the opposite sides thereof in the direction perpendicular to the propagation direction of a surface acoustic wave; the first end portion of the first IDT and the second end portion of the third IDT are each connected to the unbalanced signal terminal; and the second end portion of the first IDT and the first end portion of the third IDT are each connected to the ground potential. Therefore, parasitic impedances are each added to the first and second balanced signal terminals substantially equally. Thereby, the degree of balance outside the pass band is improved. Hence, a surface acoustic wave filter having a balanced-to-unbalanced conversion function and exhibiting a large attenuation outside the pass band can be provided, as in the case of the first invention.

[0059]

In accordance with the third invention, since the first end portion of the first IDT and the second end portion of

the third IDT are each connected to the first balanced signal terminal, and the second end portion of the first IDT and the first end portion of the third IDT are each connected to the second balanced signal terminal, parasitic impedances are each added to the first and second balanced signal terminals substantially equally, as in the cases described above. Thereby, the degree of balance outside the pass band is improved. It is, therefore, possible to provide a surface acoustic wave filter having a balanced-to-unbalanced conversion function and exhibiting a large attenuation outside the pass band.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a schematic plan view showing a surface acoustic wave filter in accordance with a first embodiment of the present invention.

[Fig. 2]

Fig. 2 is a diagram showing the attenuation-frequency characteristic of the surface acoustic wave filter in accordance with the first embodiment.

[Fig. 3]

Fig. 3 is a schematic plan view showing the electrode structure of a conventional surface acoustic wave filter prepared for comparison.

[Fig. 4]

Fig. 4 is a diagram showing the attenuation-frequency characteristic of the conventional surface acoustic wave filter prepared for comparison, which is shown in Fig. 3.

[Fig. 5]

Fig. 5 is a schematic plan view explaining a surface acoustic wave filter in accordance with a modification of the first embodiment.

[Fig. 6]

Fig. 6 is a schematic plan view showing the electrode structure of a longitudinally-coupled resonator-type surface acoustic wave filter in accordance with a second embodiment of the present invention.

[Fig. 7]

Fig. 7 is a schematic plan view explaining a modification of the longitudinally-coupled resonator-type surface acoustic wave filter in accordance with the second embodiment.

[Fig. 8]

Fig. 8 is a schematic plan view explaining another modification of the longitudinally-coupled resonator-type surface acoustic wave filter in accordance with the second embodiment.

[Fig. 9]

Fig. 9 is a schematic plan view explaining a surface acoustic wave filter in accordance with a third embodiment

of the present invention.

[Fig. 10]

Fig. 10 is a schematic block diagram showing a communication device constructed using the surface acoustic wave filter in accordance with the present invention.

[Fig. 11]

Fig. 11 is a schematic plan view explaining a conventional surface acoustic wave filter.

[Reference Numerals]

160: communication device

161: antenna

162: duplexer

163 and 166: mixers

164: surface acoustic wave filter

165: amplifier

167: amplifier

168: surface acoustic wave filter

200: surface acoustic wave filter

201: longitudinally-coupled resonator-type surface acoustic wave filter

202 and 203: surface acoustic wave resonators

204 to 206: first to third IDTs

204a, 205a, and 206a: first end portions

204b, 205b, and 206b: second end portions

207 and 208: reflectors

209: unbalanced signal terminal

210 and 211: first and second balanced signal terminals

212 and 213: electrode fingers

250: surface acoustic wave filter

401: longitudinally-coupled resonator-type surface acoustic wave filter

402 to 404: first to third IDTs

402a, 403a, and 404a: first end portions

402b, 403b, and 404b: second end portions

405 and 406: reflectors

407 and 408: first and second balanced signal terminals

409: unbalanced signal terminal

411 and 412: IDTs

500: surface acoustic wave filter

501: longitudinally-coupled resonator-type surface acoustic wave filter

502 and 503: surface acoustic wave resonators

504 and 506: first and third IDTs

505: IDT

505A and 505B: IDT portions

507 and 508: reflectors

JP Application No. 2000-363316

[Name of Document] ABSTRACT

[Abstract]

[Object] To provide a longitudinally-coupled resonator-type surface acoustic wave filter which has a balanced-to-unbalanced conversion function, which is capable of improving the degree of balance outside the pass band, and which allows the attenuation outside the pass band to be increased.

[Solving Method] A surface acoustic wave filter 200 having a construction such that at least first to third IDTs 204 to 206 are arranged along the propagation direction of a surface acoustic wave, that, among the plurality of IDTs 204 to 206, the IDTs 204 and 206 on the opposite sides are disposed in an approximate point-symmetry about the central IDT 205, and that parasitic impedances are each added to first and second balanced signal terminals 210 and 211 substantially equally.

[Selected Figure] Fig. 1